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Membrane bioreactor technology for the treatment of greywater from a sports and leisure club

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Abstract

Especially in the Mediterranean region water is a scarce resource and new approaches to water supply need to be focused. An important contribution can be realised by greywater recycling in decentralised structures. This paper describes the results of a technical feasibility study to treat greywater with membrane technology in view of its reuse for applications which do not require potable water quality. A 3L-lab-scale membrane bioreactor (MBR) treating the shower effluent from a sports club in Rabat, Morocco, was operated with a hollow fibre membrane (Zeeweed, Zenon) for 137 consecutive days. Removal performance and membrane behaviour were assessed. The permeate was of excellent quality and complied with commonly proposed standards for domestic reuse except for bacterial contamination. Non-detectable levels of faecal coliform could not be continuously guaranteed due to bacterial re-growth in the permeate pipe from the open permeate storage tank.

Keywords: Membrane bioreactor; Greywater; Shower effluent; Sports club

1. Introduction

In recent years, membrane bioreactor (MBR) technology has gained popularity in wastewater treatment and especially for decentralised and reuse applications [1–4]. The technology consists of a compact unit which combines activated sludge treatment for the removal of biodegradable pollutants and a membrane for solid/liquid separation. MBRs have a small footprint making them attractive where space is limited and water treatment for internal recycling is desirable, e.g. for buildings (equipments being generally located in the cellar) or on ships. Further advantages of the

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Table 3
Water quality standards for domestic wastewater recylcing (adopted from [12])

	Total coliforms $(100\,\mathrm{m\ L})^{-1}$	Faecal coliforms $(100\,\mathrm{mL})^{-1}$	BOD_5 (mg L^{-1})	Turbidity (NTU)	pH
US EPA		Non detectable	10	2	6–9
EC bathing water directive	10,000 (mandatory, m)	2000 (m)			6–9
Germany	500 (guideline, g)	100 (g)	20 (g)	1–2 (m)	6–9

a 1 m distance between the reactor and the open permeate reservoir. This explanation is supported by observations made at the Middle East Technical University in Ankara, Turkey.

The permeate characteristics in this study met commonly adopted standards regarding recycling for toilet flushing or other household uses, which do not require potable water quality [10,12] (Table 3). When zero faecal coliform levels have to be guaranteed at all times, disinfection will most probably be necessary.

3.3. Biomass development

The reactor was not inoculated for start-up. Over the first 80 days at a mean temperature of 13°C the bacteria showed a fairly constant growth rate of 19 mg $L^{-1}d^{-1}$ (Fig. 3). In a study with synthetic greywater at the Department of Chemical Engineering at the Berlin University of Technology values between 20 and 25 mg $L^{-1}d^{-1}$ were found at 15°C.

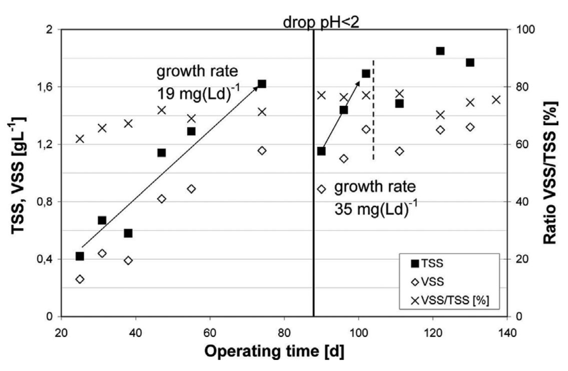

Fig. 3. Evolution of total and volatile suspended solids in the MBR.

After a pH-shock in the lab-scale MBR, which destroyed nearly 25% of the biomass, a quick recovery with a growth rate of 35 mg $L^{-1}d^{-1}$ was observed. One reason for the quicker development could be the higher average temperature (18°C) in the reactor, because the other conditions stayed constant. Another hypothesis is that due to the death of the slow growing nitrifiers a selection advantage for other faster growing organisms was given.

The mean specific growth rate lay around 0.03 d^{-1} rising from 0.029 d^{-1} to 0.032 d^{-1} in the first and second period, respectively. Above 1.3 $g_{VSS}\,L^{-1}$ biomass stayed nearly constant. This indicates that at an average food to microorganism ratio of 0.12 $g_{COD}\,g_{VSS}^{-1}\,d^{-1}$ substrate was almost exclusively consumed by endogenous respiration. Average F/M-ratios for MBR treating municipal wastewater lie in the range of 0.34…1.41 $g_{COD}\,g_{VSS}^{-1}\,d^{-1}$ [11].

During the time of operation the suspended organic solids (VSS) increased due to biomass development, but their relative contribution to the total suspended solids (TSS) stayed almost constant. Fig. 4 shows that after a slight initial increase the VSS/TSS-ratio stabilised at 76% indicating that about one fourth of the TSS in the reactor was particulate inorganic. No accumulation of external inorganic matter took place in the system, because the augmentation was due to particulate inorganics arising from biomass decay.

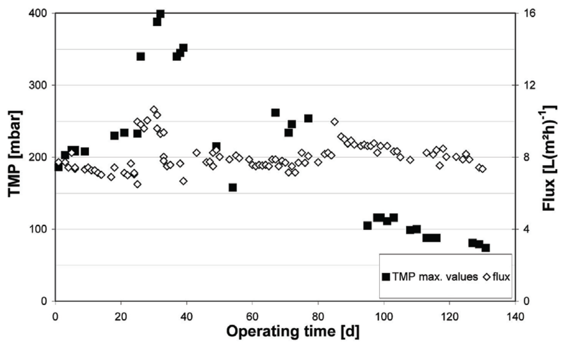

Fig. 4. Flux, maximal TMP (=highest TMP in a cycle, i.e. after 45 min of permeation).

3.4. Flux and hydraulic retention time

Stable operation was achieved at a flux of 8 L m^{-2} h^{-1} (Fig. 4) and 10 L m^{-2} h^{-1} were found to be above the critical flux. These values are at the lower end of reported literature data, because a lab-scale module was used in this study. In studies on municipal and domestic wastewater values for submerged membrane modules between 5 and 40 L m^{-2} h^{-1} are found [1].

The low flux may be explained by the fact that in the ZeeWeed membrane used in this study the hollow fibres were not flexible, and therefore not optimised for high fluxes. It gives mainly the ability to work with membrane in small batch vessels. In commercial modules fibres float in the current which creates a self-cleaning effect. Thus, working with such commercial membranes on pilot-scale would yield substantially higher fluxes.

The low flux led to an HRT of 13 h in steady state operation. Membrane cleaning with a chlorine solution provided only a short term of a reduced HRT = 11.3 h, but a dramatic reduction of TMP from 250 mbar down to 100 mbar. Although not shown in Fig. 4, the value is in the same range as in the beginning of this study, which is a month before day 0.

For economic reasons an increase of the flux is highly desirable. Removal performances of MBR treating domestic wastewater have been found to be quite independent of HRTs in the range of 2–24 h [1]. Hu [13] found an optimal HRT of only 1.5 h for greywater treatment with MBR.

4. Conclusion

This study demonstrates that MBR technology can be used to treat greywater with low COD- and low absolute nutrient content. With a ratio of 100:14:1.5 COD:NH_3:P the relative nutrient content was high in comparison to that observed by other authors.

The permeate characteristics met commonly adopted standards for recycling for toilet flushing or other household uses, which do not require potable water quality. To guarantee zero faecal coliform levels at all times, disinfection of the permeate is very likely to be necessary. The permeate was of excellent aesthetic quality and free from odours, a fact that is very important in view of public acceptance of treated water recycling.

An important drawback of MBR technology remains its high investment cost. If flux cannot be increased the required membrane area and associated costs will be high. Moreover, there is a need for power supply for aeration and mixing. However, in cases of space limitation like e.g. in hotels or leisure clubs, the small footprint of the MBR can outweigh these inconveniences.

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